opening pathways where obstacles now exist. Furthermore, the desirable cooperation between investigators would become a much simpler matter to arrange than it is now. Every laboratory for research would become a nucleus around which individual enterprises might cluster, each giving and receiving help. A great work, wisely planned, always attracts colaborers; its mere suggestiveness is enough to provoke widespread intellectual activity. Here there is no monopoly, no limit to competition, no harmful rivalry; every research is the seed of other researches, and every advance made by one scholar implies the advance of all. In the realm of thought we gain by giving; and the more lavish our offerings, the richer we become.

We glory in the achievements of chemistry, and we find merit also in its imperfections, for they give us something more to do. Never can the work be finished, never can all its possibilities be known. Hitherto the science has grown slowly and irregularly, testing its strength from step to step, and securing a sure foothold in the world. Now comes the time for better things; for system, for organization, for transforming the art of investigation itself into something like a science. The endowment of research is near at hand, and the results of it will exceed our most sanguine anticipations.

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U. S. GEOLOGICAL SURVEY.

GRADED CONDENSATION IN BENZINE VAPOR, AS EVIDENCED BY THE DISTORTED CORONAS AND MARKED AXIAL COLOR EFFECTS ATTENDING CLOUDY CONDENSATION.

1. It would be difficult to read the admirable work on the relation of rain and atmospheric electricity which has issued from the Cavendish Laboratory, without being convinced of the strength of the arguments put forth. That in a repetition of these researches, in particular of the experiments of C. T. R. Wilson* on the comparative efficiency as condensation nuclei of positively and negatively charged ions, one would but reproduce his results admits of no doubt.

In so important a question, however, it is none the less desirable to reach identical conclusions from entirely different methods of approach. It has been part of my purpose to be driven to like inferences; in other words, to reach a point in my work where I should have to abandon the nucleus as an agency which for purely mechanical or thermodynamic reasons facilitates condensation, and be compelled to recognize the special activity due to its charge.

I had hoped to accomplish this in the following experiments with benzine when contrasted with the corresponding behavior of water; but the results, contrary to my expectation, are so curious and pronounced an accentuation of the nuclear theory that it seems worth while to specially describe them.

2. The work originated in the following point of view: if the action promoting condensation is in any degree of a chemical nature (such suppositions have been made; the production of hydrogen superoxide, for instance, has been suggested), then there should be a marked difference in the efficacy of the same nucleus when the saturated water vapor is replaced by the vapor of some electrolytically neutral liquid, like a hydrocarbon. I accordingly made a series of experiments with benzine, endeavoring at first to utilize benzine jet and color tube in the usual way. In this I failed for reasons without much relevant interest here. I then adopted the method of adiabatic cooling, partially exhausting a spherical receiver (Coulier, Kiessling) about 23 cm. in diameter, illuminated by

*C. T. R. Wilson, *Phil. Trans.*, London, Vol. CXCIII., pp. 289–308, 1899.

white light diverging from an external point. In this way not only were copious fogs obtained, but the coronas* produced were additionally available as evidence.

In the benzine jet, particles are probably cooled too suddenly, and at once attain a size incompatible with axial color effects. Using the exhaustion method, however, these axial colors appearing in benzine are not only of pronounced depth, but they run into higher orders than in the case of moist air subjected to like exhaustions. Sequences passing through blue, green, yellow, brown, purple, etc., green, brown, etc., may be seen in the axis of a column only 23 cm. long. The reason, no doubt, is the lower latent heat of benzine, insuring the formation of drops not less uniform, but of a size, cæt. par., regularly larger than for water vapor. The fact that axial colors are producible both with water and with a pronounced insulator like benzine, is a result of fundamental importance in its bearing on any theory adduced to account for the axial absorption in question.

3. The exhaustion experiments were thus at once successful. Cloudy condensation was as densely produced in benzine vapor as in water vapor, with phosphorus, flame and other nuclei. Care was taken to insure dryness of vessel by test experiments both before the benzine was introduced and after it had been quite removed by evaporation. The exhaustion of about one sixth, say 13 cm., seemed best adapted to bring out the following phenomena. When the receiver was left standing overnight no marked condensation occurred in the absence of nucleation, or else the condensation was rain, like a fine mist, falling about 2 or 3 cm. per second.

The introductory experiments were made with light nearly in parallel, the sun's image being used as a coronal center. The even dense tawny benzine fog after the first nucleation was expected to develop on subsequent exhaustions (each followed by an influx of filtered air) into the magnificent coronas which characterize this experiment in the case of water vapor. On the contrary, however, the fogs were more fleeting, showed a more rapid descent than aqueous fogs, and the color fields obtained were not ring-shaped as expected, but *sharply stratified horizontally,* roughly speaking, in alternations of green and red.

Moreover, if the exhaustions were made successive without influx of air between each, the colors rose in strata from below, as they fell in strata when left to themselves. On mounting, the strata grew successively wider and thinner till they vanished from sight, brown, yellow-white being the last colors observed. Uniform color fields (strata of limiting width) were eventually producible in this way. Yellow, brown, crimson, arose from a whitish blue base, then descended again on completed exhaustion, reminding one of the extension of an accordion. The speed of apparent viscous subsidence of the top bands has no direct meaning, since fall (or rise) is here complicated by evaporation.

On entrance of air, vortices were evidenced by ring-shaped threads of color so that mixture was at first inevitable. One must wait till this ceases before again exhausting. Convection currents due to local reheating of the adiabatically cooled gas by the walls of the receiver, were equally apparent, stringy colors rising on the out-

*For some time I have been making experiments with the coronas of cloudy condensation on a large scale, with the purpose of comparing the diffraction colors so produced with the axial colors of the steam jet. The latter are almost complementary to the colors of the central patches of the corresponding coronas, betraying a difference of origin in the two cases of great theoretical interest. One is tempted to infer that the light axially absorbed illuminates the colored inner circle of the corona, but the proof of such an assertion is a long stride.

side and descending into the middle of the receiver. It is the phenomenon which interferes with the usefulness of narrow tubular apparatus.

4. As this subsidence of color bands in benzine vapor is an observation of importance, I resolved to repeat the work under more normal conditions. Accordingly I used as my source of light the bright area of the mantle of a Welsbach burner, seen through a small hole in the metallic screen by an eye, looking centrally through the receiver containing saturated benzine vapor and nucleated air. Punk nuclei replaced the phosphorus nuclei. On exhaustion (without nucleation) after standing overnight, the coronas were white centered fringed with brown, about as large as ordinary lycopodium coronas seen under like conditions. These large drops are a proof of the relative absence of nuclei initially.

After nucleation the first dense fogs were vaguely annular during the first five successive exhaustions, filtered air being supplied between each. The next five exhaustions produced more nearly, finally very fully stratified colors, in spite of the point source of light. Shaking the receiver violently at any time, so as to scatter the liquid benzine within, always reproduced a nearly perfect corona, which on standing became distorted again, in color at least. I now made special experiments, shaking the receiver before each observation, bringing out successive coronal effects* never as perfect as with water, however, always showing the tendency to stratification. The characteristic coronas succeeded each other so rapidly that it would be difficult to make them out. Nuclei, however, were still present after over two hours, the eventually white centered coronas showing a continued shrinkage to smaller diameters in accordance with the diminishing number of nuclei present. Twenty exhaustions did not remove them.

Here, as above, therefore, the fleeting character of the coronas, their tendency to depart from the normal annular character into stratification, the speed of descent of the color bands, their rise upward on exhaustion like a fog from a lake, are the special characteristics of the colored cloudy condensation occurring in benzine. To these are to be added the striking axial colors mentioned above.

5. To explain the above phenomena in their variation from the normal aqueous corona, it is first necessary to account for the more rapid subsidence of nuclei. I am not aware of appreciable differences of viscosity in the two vapors; but benzine has the smaller latent heat of evaporation by over seven times. Hence under identical conditions of nucleation and for like exhaustions or like adiabatic cooling of a given mass of saturated air, the drops would be larger, the colors more advanced in benzine than in water; and since the square of radius is in question, this would point to subsidence of the loaded nuclei in benzine nearly four times more rapid. It would also account for more rapid evaporation or more fleeting colors, which is the case.

Again, if the loaded nuclei be regarded as mechanical particles, the largest will eventually be found in the lower strata, the smallest in the upper strata, as in a case of ordinary subsidence of suspended matter in water. It is well known, moreover, that smaller droplets wane, larger droplets grow. Hence on increasing exhaustion condensation takes place first at the bottom and last at the top, since the smallest nuclei correspond to greatest vapor pressure or difficulty in condensation, and since the largest nuclei have been loaded with condensed liquid first, have parted with it last, have had greater time

*These will be described for water vapor in a subsequent paper.

in falling and have therefore sunk deepest before losing their liquid load. The strata mount upward as fresh exhaustion proceeds. The last colors to appear are the browns and yellows of the first order, also seen in the steam tube for vanishing condensations. The whole phenomenon is thus the result of strata of invisible nuclei, *graded in virtue of the loading mechanism,* and partakes throughout of a mechanical character to the extent that the nuclei are *not even a uniform product.* The forced distribution is sufficiently powerful to entirely mask the elementary optical phenomenon.*

On shaking the liquid benzine in the receiver uniform distribution is again promoted, with the result that annular coronas reappear. It is particularly to be noticed that subsidence is due to loaded nuclei. The free nucleus does not appreciably descend. Even with water vapor, loading does not produce stratification. Water fogs when exceptionally dense may sometimes be seen to rise, but the diffraction pattern is always annular and usually without color distortion.

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* Since writing the above I have made similar experiments with benzol, reaching the additional result that nuclei are produced by the liquid itself, *spontaneously,* in the dark. They ascend against gravity in horizontal strata, at the rate of 2 or 3 cm. per sec. in the lower hemisphere. They may be completely precipitated by partial exhaustion, leaving the air in the vessel free from nuclei (but the above flask will be refilled to saturation in 10 or 20 minutes). The experiment may be repeated any number of times. The sharp demarcation of the pure air above from the rising surface of nuclei is beautifully evidenced by the coronas, which are annularly perfect for axial beams below the surface, asymptotically *bowl-shaped* at the surface, and absent for axial beams above the surface. Shaking produces the coronas from pure air instantly, but these are usually smaller. In so far as the spontaneous coronas have fixed diameters for fixed exhaustions (supersaturation), the number of nuclei eventually reaches a maximum or saturation. Among many interesting problems growing out of the present observations, the corresponding behavior of water is most important.

DATA ON SONG IN BIRDS: THE ACQUISITION OF NEW SONGS.

The purpose of this paper is to set forth the evidence that has come under the writer's personal observation regarding the propensity of birds to acquire new methods of expression in song.

This faculty may be properly divided into three categories: First, the disposition of wild birds to interpolate new phrasing into what may be called their normal song, or *to acquire new songs.* Second, education of expression, by direct teaching from man to birds in confinement. Third, the propensity of caged birds to imitate, voluntarily, sounds that attract their attention.

The evidence under the first division of this thesis is absolute and also well known. However, a few special cases may serve to emphasize the matter.

Every trained field ornithologist discriminates individuality in song, and some have been so fortunate as to have noted wide and radical departures from what I have distinguished as the normal song. The slight variation from the normal is of too common occurrence to be dwelt on here. Suffice to say that as set forth in a previous paper in this journal,* most observers recognize degrees of excellence in the songs of wild birds of the same kind.

Again, a few observers have heard wild birds imitate or produce not only the songs of other birds, but also the barking of dogs, human speech and mechanically produced sounds such as the creaking of a wheel, the filing of a saw and the like. The facility

* See Science, October 4, 1901, p. 522.